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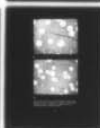   JUL 79 R C FILZ
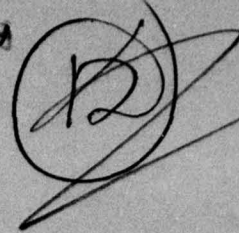UNCLASSIFIED   AFGL-TR-79-0156   NL

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Long Duration Exposure Emulsion Package (LDEEP)
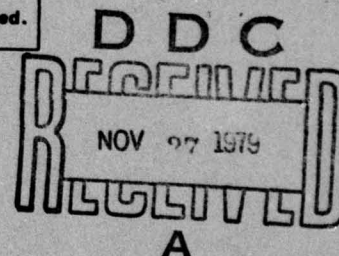
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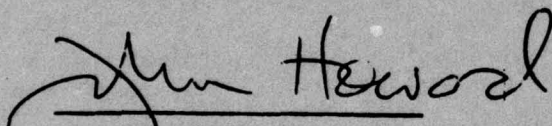HANSCOM AFB, MASSACHUSETTS 01731

AIR FORCE SYSTEMS COMMAND, USAF

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FOR THE COMMANDER

Chief Scientist

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
An exposure package has been designed to obtain measurements of trapped proton fluxes utilizing the NASA Long Duration Exposure Facility. The techniques are similar to those used in the 1960's to obtain trapped proton fluxes from Air Force recoverable satellites. The main novelty consists in the development of proton sensitive plastic detectors capable of withstanding the six-month exposure planned for LDEF. At the planned LDEF altitude of 450 km, unshielded nuclear emulsion would become grossly over-exposed

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20. Abstract (Continued)

in six months. Early designs for LDEEP consisted of shielded emulsions with narrow cylindrical openings to allow trapped protons to enter. The discovery of the CR39 plastic detector by Cartwright et al opens up a new solution to this problem. The potential for obtaining the first reliable measurements of inner zone trapped protons of 1 to 10 MeV energy is discussed. Earlier electronic counter measurements are quite uncertain, and the NERV emulsion results covered far too brief a time interval and were spatially limited.

Preface

I would like to thank Lenwood Clark of NASA Langley Research Center for his assistance throughout the design of LDEEP and Joe Geary of AFGL for his pains-taking, careful design. Albert Davis and Dr. Vanket Rao of Emmanuel College assisted in the development of techniques of utilizing CR39 to detect high energy protons. Dr. P. J. McNulty of Clarkson College arranged the proton exposures at Brookhaven National Laboratory.

Illustrations

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Long Duration Exposure
Emulsion Package (LDEEP)

    The Long Duration Exposure Facility will be placed in a 450-km circular, 30° inclination orbit around November 1981 by the space shuttle and recovered approximately six months later. The facility consists of a twelve-sided cylinder (Figure 1) 30 feet long by 14 feet in diameter. Each side consists of six trays of experiments and each end has eight trays. This experiment will occupy one-sixth of a tray on three sides and one-fourth of a tray on the earth side. Appropriate mounting panels allow four equal boxes 12 inches square by 5 inches to be used as shown in Figure 2.

    LDEF will be gravity gradient stabilized and carefully placed so that total stabilization will occur through most of the six months. Under these conditions the orbital exposure to trapped protons in the south Atlantic will closely approximate those which prevailed on Air Force satellites during the 1960's (Filz and Holeman[1]). During this period a study of trapped proton fluxes was carried out in this laboratory resulting in the long-time history of 55 MeV protons shown in Figure 3. Measurements on lower energy protons were not possible because of fixed absorber over the nuclear emulsions used in that study. The only emulsion measurement of very low energy proton fluxes was made on a single rocket flight—

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1. Filz, R.C. and Holeman, E. (1965) Time and altitude dependence of 55-MeV trapped protons, J. Geophys. Res. 70:5807.

the NERV study (Naugle and Kniffen[2]) which showed virtually no low energy protons in the inner radiation belt (Figure 4). The most reliable measurement of low energy proton flux in this region was obtained by a four-month average of data taken by the particle identifier instrument in 1972-73. The individual observations are shown in Figure 5. Because of the small solid angle area factor of this counter there were no counts at all in the 5 to 7 MeV channel and only a few counts in the 7 to 11 MeV channel. Only the highest energy channel shows sufficient statistics for a good proton flux determination. Because of the large number of high energy protons which penetrate this instrument during the flight, it is also possible that the low energy proton counts are background and the true intensities are lower.

Figure 6 shows the mirror plane geometry for trapped protons. Figure 7 shows the distribution of arrival directions for trapped protons derived from emulsion measurements on an Air Force Satellite. For the LDEF 30° inclination, most of the trapped protons will be detected between 25° and 30° south latitude, and the variation of magnetic inclination with L shell is shown in Figure 8. Figure 9 shows the percent of time as a function of south latitude and the approximate percent of trapped protons detected as a function of south latitude for a 450-km circular orbit with 30° inclination.

This experiment will consist of a group of stacks of CR39 plastic arranged to look into the trapped proton mirror planes at various L values (Cartwright et al[3]). Figure 10 is an isometric view showing a representative arrangement. CR39 is an ideal detector for this purpose because:

1. Protons up to 4 MeV are clearly visible and easy to count (Rao et al[4]).

2. The track etch rate is only slightly greater than the bulk etch rate for protons, so only normally incident protons record.

3. This makes CR39 a narrow-angle, large-area detector with low background.

4. Thermal problems are reduced compared to emulsion.

5. Simple diameter measurements indicate the energy of the proton.

Figure 11a shows a picture of normally incident 1.5 MeV protons on CR39 while Figure 11b shows 2.2 MeV protons. A clear discrimination is visually obvious,

2. Naugle, J.E. and Kniffen, D.A. (1961) Flux and energy spectra of the protons in the inner Can Allen belt, Phys. Rev. Letters 7:3.

3. Cartwright, B.G., Shirk, E.K., and Price, P.B. (1978) A nuclear-track-recording polymer of unique sensitivity and resolution, Nucl. Instrum. Meth. 153:457.

4. Rao, R.V. and Davis, A., Filz, R.C., McNulty, P.J., and Shirkey, D. (1979) Calibration of CR39 Plastic Track Detector for Low Energy Protons, Tenth International Conference on Solid State Nuclear Track Detectors, Lyon, France (to be published).

and individual diameter measurements show discrimination of these two energies on an individual track basis.

Our observations of proton tracks in CR39 do show differences in sensitivity to the manufacturing process, and the flight detectors must be calibrated directly.

It is expected that the LDEF flight will yield detailed differential trapped proton spectra in the energy range 1 to 100 MeV for the 450-km altitude region of the inner Van Allen belt. This data will be used to provide accurate proton flux models for space systems designers and to assist in defining the trapped proton source and loss processes.
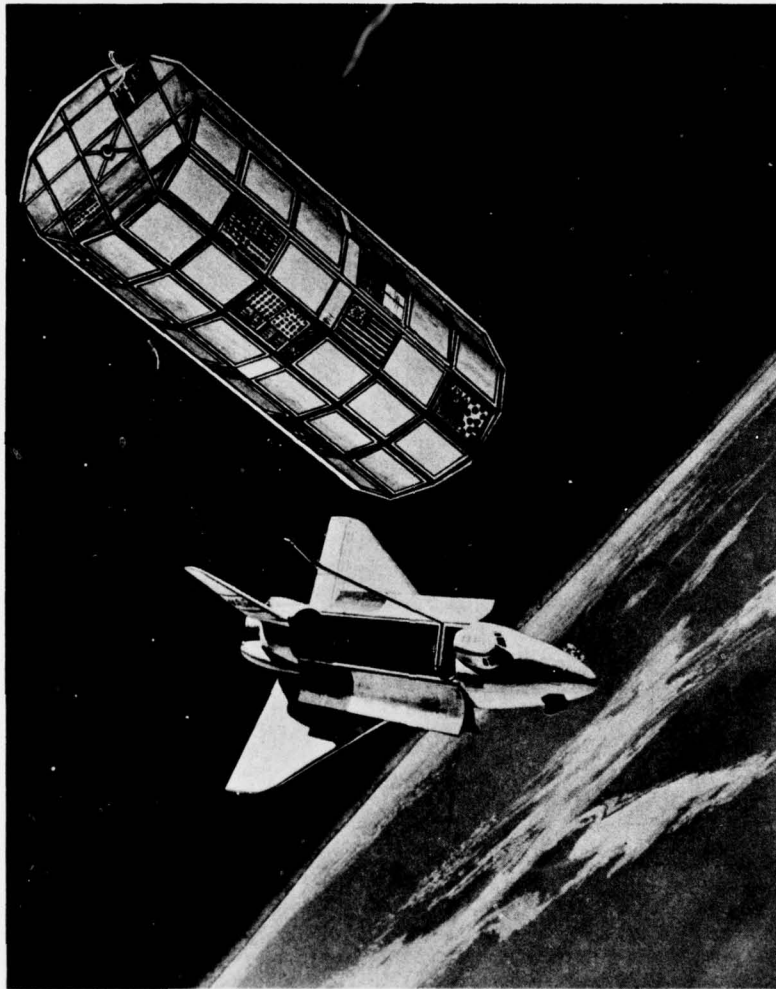

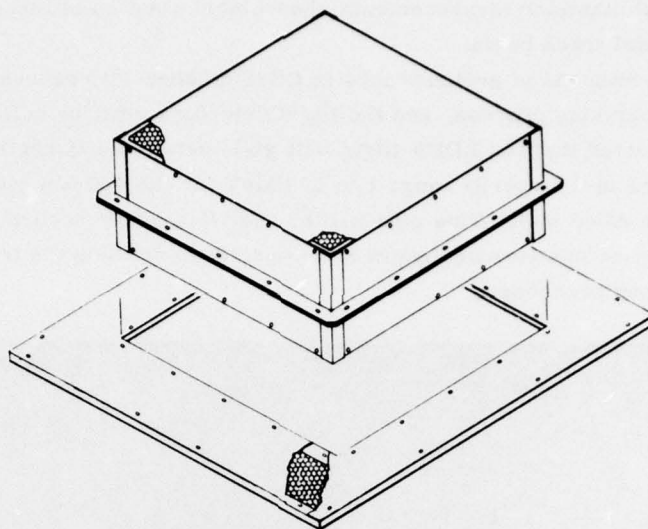Figure 1. A View of the Long Duration Exposure Facility in Orbit (NASA Langley)

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Figure 2.   The 12-Inch Square by 5-Inch LDEEP Box Showing the Support Panel Which Mounts on the LDEF Tray.   This occupies 1/6 of a side tray or 1/4 of an end tray
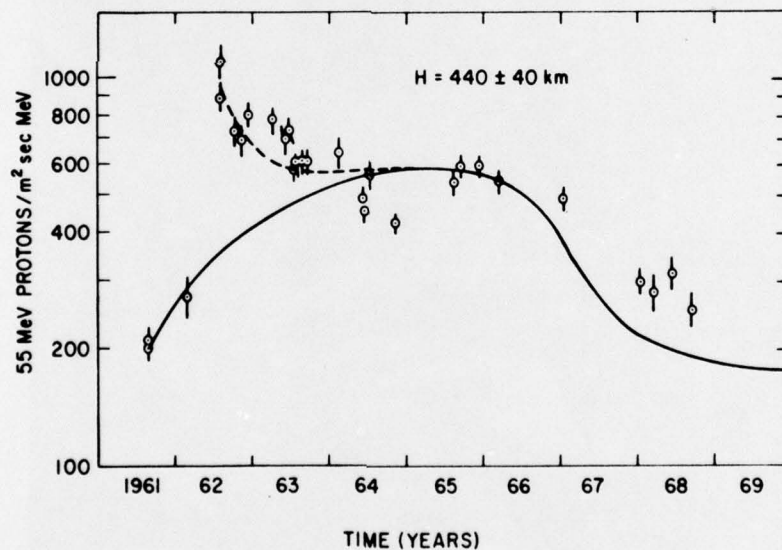

Figure 3.   The Time Variation of 55 MeV Trapped Proton Fluxes Measured with Nuclear Emulsions Exposed on Oriented Polar Orbiting Air Force Satellites.   The solid curve is the time variation expected from changes in the loss rate in the solar cycle varying atmosphere.
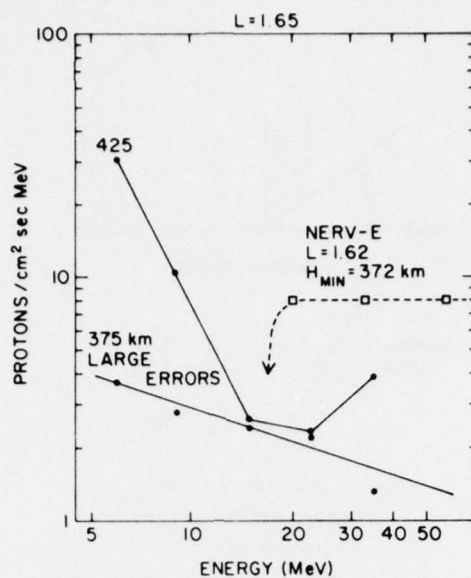
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Figure 4. A Comparison of the NERV Emulsion Data with Particle Identifier Data. The absence of NERV protons less than 20 MeV raises questions of the reliability of proton flux measurements in this energy interval
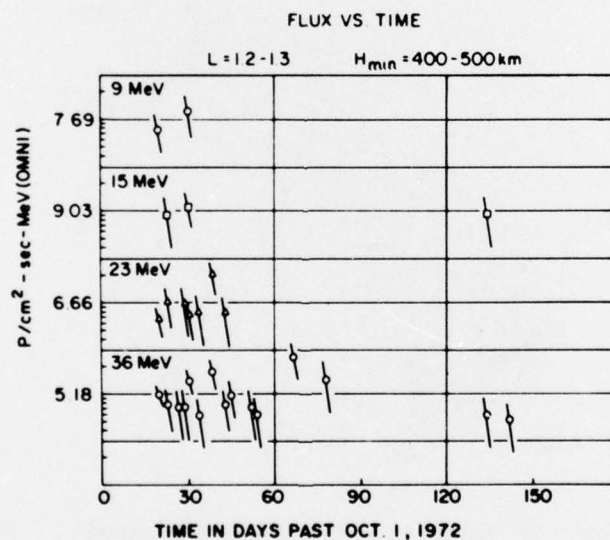

Figure 5. Trapped Proton Data Obtained by the Particle Identifier Instrument on Air Force Satellite 72-1. The poor statistical weight is typical of narrow angle electronic detectors. The lowest energy protons could be back ground created by higher energy protons.

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WEST — θ — D — r — EAST

MIRROR PLANE

B — MIRROR PLANE — D — i — d — H_c — H — i

MAGNETIC MERIDIAN PLANE
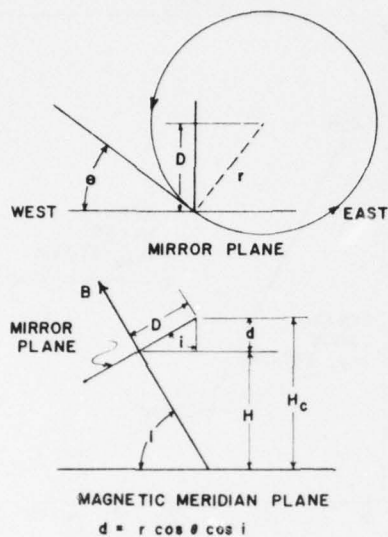
$d = r \cos \theta \cos i$

Figure 6. The Mirror Plane Geometry Encountered in the South Atlantic. The magnetic meridian plane makes an angle of "declination" with the true north direction

ZENITH

L SHELL AT B_{MIN}

1.14
1.16
1.19
1.26
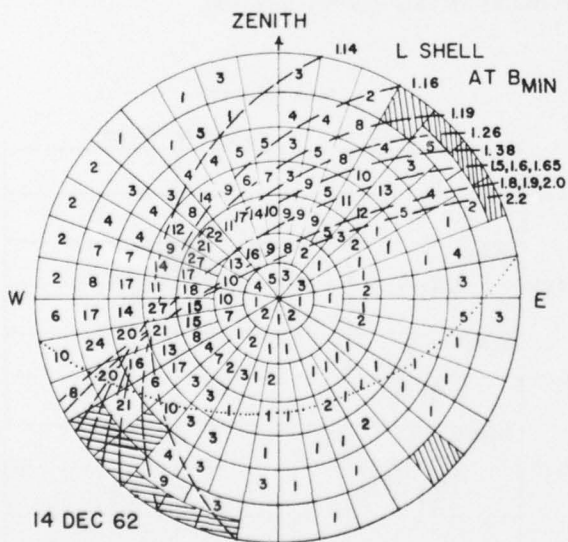1.38
1.5, 1.6, 1.65
1.8, 1.9, 2.0
2.2

W

E

14 DEC 62

Figure 7. The Intensities of 55 MeV Trapped Proton Fluxes Detected on Orientated Air Force Satellites During Passage Through the South Atlantic. The well defined trapped proton mirror plane will also exist on the LDEF flight
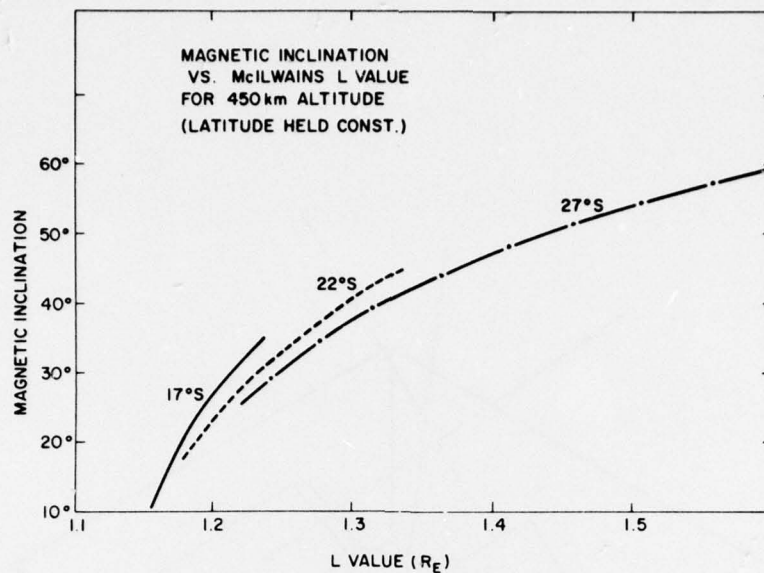
12

Figure 8. Variation of Magnetic Inclination with McIlwains L Value for Constant South Latitudes of 17°, 22° and 27°S for a 30° Inclination Satellite at 450-Km Circular Orbit
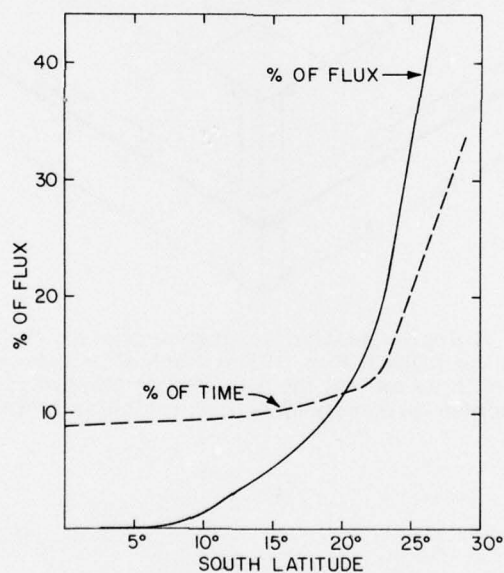

Figure 9. Approximate Weighing factors for a 30° Inclination Satellite Exposed to Trapped Protons at 450-Km Circular Polar Orbit. Dashed line gives the percent of time as a fraction of latitude. Solid line gives approximate percent of integrated trapped proton flux
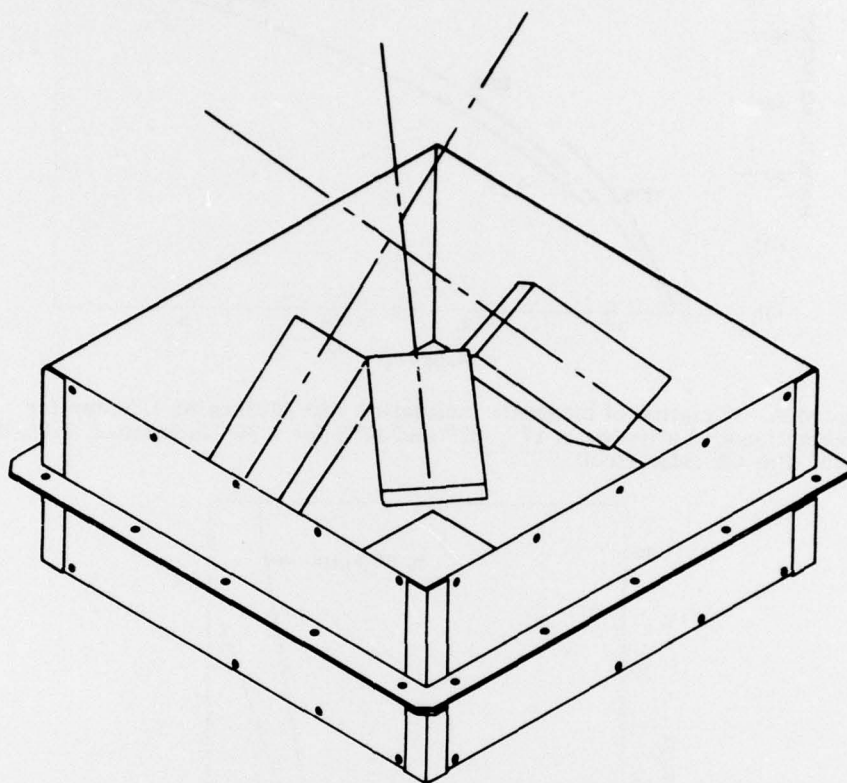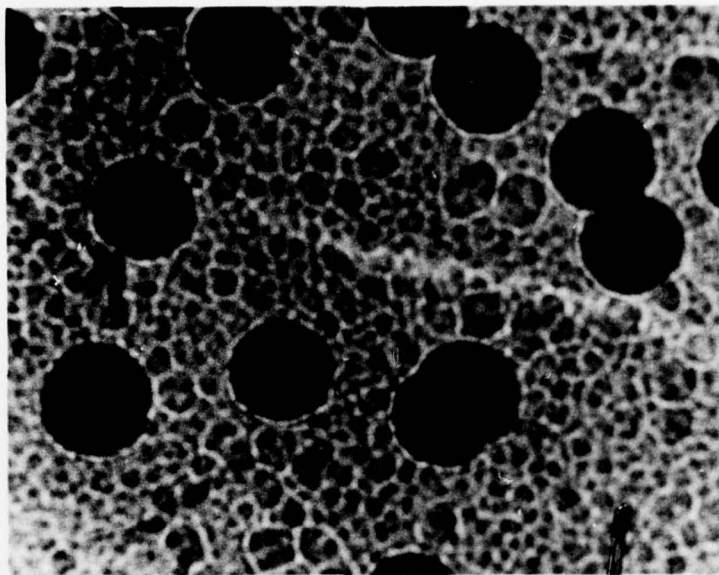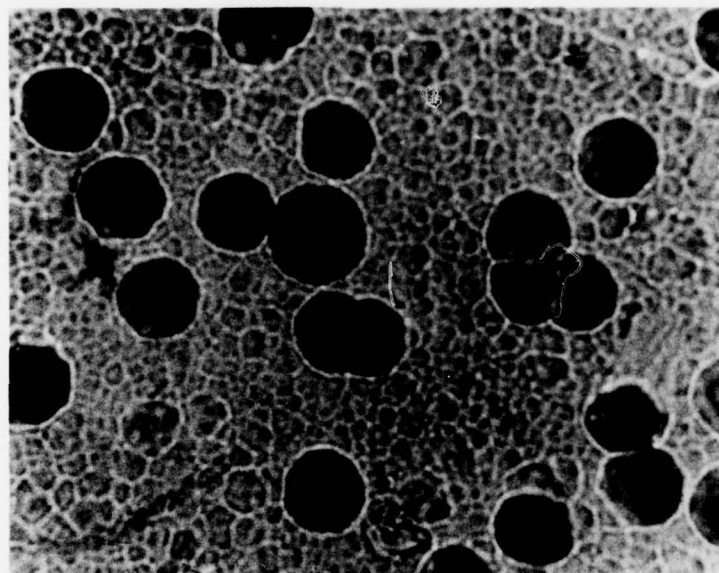
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Figure 10. A Representative Arrangement of Small CR39 Pack-
ages Within the LDEEP Box. Each stack of 2-inch square CR39's
is oriented with its axis in the appropriate trapped mirror plane
such that incident protons will be perpendicular to the plastic
surface

a

b

Figure 11. Appearance of Normal Incidence Proton Etch
Pits on CR39. a. 1.5 Mev, b. 2.2 MeV. A clear visual
difference is seen. Quantitative measurements allow
individual separation at these energies

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